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In lakes but not in minds: Stakeholder knowledge of invasive species in prairie lakes

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Abstract

Humans are key vectors in the spread and establishment of aquatic invasive species (AIS), and human behavior can exacerbate or help prevent further spread of non-native species. Therefore, stakeholders' knowledge is critical to preventing establishment of AIS. However, stakeholders' AIS knowledge in prairie lakes remains poorly understood. We used a survey questionnaire in Saskatchewan, Canada, to assess the state of AIS knowledge, identify predictors of knowledge, and optimize management strategies. Statistical analyses of the responses of 440 participants indicated a generally low level of AIS knowledge, suggesting low communication success. Respondents were generally more aware of non-native fishes than plants. Of concern was the observation of substantial knowledge gaps regarding non-native mussels and important preventative behaviors that may have devastating ecological, social, and economic consequences if left unaddressed. Better understanding of AIS issues was significantly associated with several trans-situational (age, sex and education), situational (recreational purpose and using multiple lakes), and lake-related knowledge (awareness of eutrophication) predictors. Exploitation of these predictors is recommended to improve effectiveness of outreach and communication efforts. Specifically, we propose that management strategies focus on improving communications by streamlining outreach messages, targeting low-knowledge groups (e.g., swimmers, cabin owners), and expanding education campaigns.

Keywords: AIS knowledge; prairie lakes; survey research; knowledge predictors; outreach; communications strategy.

Introduction

Invasive species are a critical threat to freshwater ecosystems in North America (Dextrase and Mandrak 2006). Their spread is tightly linked to human activities (e.g., economic development, disturbance, travel, trade), which can result in accidental or deliberate introductions of non-native species to new habitats (Drake et al. 2014; Edwards et al. 2016; Gates et al. 2009; Touza et al. 2014). Therefore, human behavior, including knowledge of environmental issues, should be a key component of efforts regulating the spread of invasive species (Bremner and Park 2007; Jetter and Paine 2004; Shackleton and Shackleton 2016). Support for invasive species management increases with the public`s understanding of invasive species' biology and mechanisms of prevention or control. But uneven education of the public regarding invasive species can also lead to divisive debates on the desirability of, control and eradication efforts (Bremner and Park 2007). In particular, lack of community consensus for eradication of invasive species can cause management efforts to fail (García-Llorente et al. 2008; Moon et al. 2015). Support for management efforts can markedly increase when focus group discussions with stakeholders relay the rationale and methodology of invasive species eradication (Bremner and Park 2007). Findings suggest that stakeholders' knowledge about invasive species can influence their prevention, spread, and control, both through direct public action and support for management strategies (Ansong and Pickering 2015; Carlson and Vondracek 2014; Ford-Thompson et al. 2015; Sharp et al. 2011).

Quantitative assessment of stakeholders' knowledge concerning aquatic invasive species (AIS) is a critical first step in facilitating optimal human behaviors and developing stakeholders support for effective management strategies. For example, an econometric investigation of AIS awareness and knowledge determinants of near-lake property owners revealed that collegeeducated water recreationists and boat owners who visited lakes outside their area are more likely to be aware of different aspects of AIS compared to non-recreationists (Eiswerth et al. 2011). In general, active members of formal associations (e.g., lake stewardships, fishing groups) are more likely to be knowledgeable about AIS and less prone to engage in risky behaviors than non-members, even when the latter exhibited some understanding of AIS issues (Gates et al. 2009; Eiswerth et al. 2011). However, those exhibiting passive membership in such organizations may falsely report a degree of higher environmental awareness than is supported by their factual knowledge (Heck et al. 2016). Low levels of awareness and concern can also lead to risky behaviors associated with AIS spread, such as incomplete cleaning of personal items and equipment (Gates et al. 2009). Overall, surveys suggest that fishers are more knowledgeable about AIS and outreach campaigns than other recreationists (water skiers, swimmers, etc.), but their participation in AIS prevention behaviors is inconsistent or low and depends on fishing experience (Edwards et al. 2016; Eiswerth et al. 2011; Gates et al. 2009; Lindgren 2006; Seekamp et al. 2016).

As with other environmental issues (Dean et al. 2016) preventative behaviors are usually positively correlated with stakeholders' AIS knowledge (Gates et al. 2009), but confounding or undesirable outcomes can arise despite high understanding of AIS. For example, transient boaters are more likely to reuse the same bait in different water bodies compared to other boaters, even though all boaters tend to have attitudes and beliefs that support AIS spread prevention (Witzling et al. 2016). Some studies have found that even educated fishers are likely (25-33%) to release live bait into water bodies (Lindgren 2006; Drake et al. 2014). Similarly, well-informed fishers and boaters often did not properly rinse used equipment (Connelly et al.

2016; Seekamp et al. 2016). Disposition for risky behavior may be attributed to stakeholders tendency to underestimate the ecological costs of individual actions (Drake et al. 2014).

Additionally, trans-situational or situational predictors of AIS knowledge may also affect the success of AIS outreach and education campaigns (Eiswerth et al. 2011). Trans-situational factors are variables that generally remain static regardless of the situation (e.g., age, sex and education). These variables have been shown to influence levels of environmental knowledge in many countries (Dean et al. 2016; Heck et al. 2016; Pierce et al. 2010; Steel et al. 2005a; Steel et al. 2005b). Better educated, older, males tend to be more knowledgeable about public policy issues, although the gender gap is closing in the younger population (Otto and Kaiser 2014; Pierce et al. 2010; Steel et al. 2005a; Steel et al. 2005b), and may be becoming more dependent on the specific environmental issue (Dean et al. 2016; Harvey et al. 2016; Otto and Kaiser 2014). In contrast, context-dependent situational variables arise as a result of encounters between individuals and their environments irrespective of individual characteristics like age, sex and education (Belk 1975; Dean et al. 2016; Heck et al. 2016; Pierce et al. 2010; Steel et al. 2005a; Steel et al. 2005b). Situational factors are impacted by the degree of exposure to the issue and in turn, influence knowledge-seeking behavior of the stakeholders (Steel et al. 2005a; Steel et al. 2005b). Trans-situational and situational factors can interact to influence the ontogeny of environmental awareness and knowledge, but situational factors can also help override the influence of trans-situational factors. For example, coastal recreationists are more likely to be knowledgeable about important ocean and coastal issues regardless of individual trans-situational profiles (e.g., Steel et al. 2005a; Steel et al. 2005b). Given their static nature, trans-situational predictors are inherently more difficult to address through outreach and education campaigns, whereas pliable situational predictors are more receptive to communications strategies. By identifying AIS knowledge predictors and understanding their characteristics, managers have the opportunity to influence AIS knowledge by engaging in more targeted outreach which can lead to better AIS management successes.

This study aims to assess the knowledge base of diverse stakeholders associated with freshwater and sub-saline lakes of the Northern Great Plains of the Canadian prairies. Lakes are abundant in Saskatchewan (SK), Canada, and provide important ecosystem services and economic opportunities (Koob and McGuire 2013; Leavitt et al. 2006; Wissel et al. 2011), and AIS are a critical threat to water quality, native flora and fauna, recreation, and economic investments (Dextrase and Mandrak 2006; Pimentel et al. 2005). Additional information about the study region can be found in Nanayakkara and Wissel (2017). Several AIS are already present in SK and, given its geographic position, the region is considered highly vulnerable to a non-native mussel invasion (Provincial Auditor 2016). The most recent evaluation of the effectiveness of AIS outreach and education efforts was conducted in 2010 as part of a joint Federal-Provincial survey of sport-fishing in SK (Koob and McGuire 2013). Results indicated low levels of awareness (23%) among SK residents about AIS outreach efforts and similar to studies discussed earlier, identified risky watercraft use patterns that may exacerbate vulnerability to non-native mussels (Koob and McGuire 2013). Therefore, despite increased AIS outreach and education efforts (including a formal mussel strategy initiated in 2014), we contend that attempts to influence knowledge and foster preventative behaviors via communications campaigns have been ineffective in SK. We posit instead that knowledge and attitudes of the regional stakeholders towards AIS are mainly informed by trans-situational factors, particularly education. Specifically, in the present study, we seek to: 1) examine AIS knowledge levels among stakeholders to measure effectiveness of current outreach efforts; 2) evaluate the contribution of trans-situational, situational and knowledge-related variables to identify targeted outreach to increase AIS knowledge, and; 3) offer management recommendations based on findings to help ensure prevention and control of AIS.

Methods

Data for this study were obtained from the Prairie Lake Use and Management Survey (PLUMS), a 4-page self-administered questionnaire instrument that contained fixed and open-ended questions. Prior to the survey, the questionnaire was pretested in 2013 to enhance the instrument's validity and reliability (Nanayakkara and Wissel 2017). On the basis of this pilot study, we eliminated inconsistencies in the questionnaire and the survey was expanded to include AIS questions. The current questionnaire included five sections: lake-use information such as purpose of lake-use and fishing habits; knowledge of aquatic systems including awareness of eutrophication and winterkill; knowledge of invasive species; lake management strategies, including satisfaction with lake management and willingness to participate in a citizen science initiative, and; demographic information. Given the relatively small sample size in the 2013 study (65 respondents), we presented the survey in two formats, a paper as well as a web-version.

We utilized multiple methods for survey distribution and outreach to maximize participation. The survey was distributed in August 2015 using an on-site, convenience intercept survey methodology at entrance and exit points of nine study lakes in SK (Floyd et al. 1997; Luo and Deng 2008; Pan and Ryan 2009; Uysal et al. 1994). Sites chosen represent popular visitor destinations and a range of sizes and distances from population centers in the region (Figure 1). We approached 250 people on-site at beaches, boat ramps and park entrances at study lakes. Survey participants chose to complete the survey right away, mail it at a later time (stamped/addressed envelope was provided) or complete it online (link was provided) at a time of their convenience. Complete questionnaires were collected by interviewers (the lead author was the principal interviewer) on-site once they were filled out by participants. If a group of visitors was encountered, one to three (depending on the group size and composition) representatives from the group were asked to fill out questionnaires. On average, respondents spent 15 minutes filling out the questionnaires. Recruitment fliers with the web-link to the survey were placed on every other vehicle windshield in the parking lot as well. We conducted additional outreach and participant recruitment through articles (with web-link to the survey) in local newspapers and through community members. The web version was available from August 2015 to November 2015. Incentive for survey participation was provided through a prize draw to win one of three fishing rods (each valued at CAD $89.99). Questionnaire format ensured anonymity but contact information was needed for prize draw participation. Approval to complete this study was obtained from the University of Regina research ethics board.

We utilized a subset of questions on AIS and potential knowledge predictors (trans-situational, situational and lake-related knowledge) from the PLUMS survey for this study (Appendix 1). In additional 'yes/no' questions participants indicated awareness of the term 'invasive species' as well as zebra (*Dreissena polymorpha*) and quagga (*Dreissena bugensis*) mussels. Zebra and quagga mussels are currently absent in SK, but have been detected in waters to the south, east and west of the study location (Benson et al. 2017; personal communications with SK Ministry of Environment 2016). Given the potential for an invasion by these non-native mussels and the economic consequences of such an invasion (Robinson et al. 2013; Strayer 2009), the SK Ministry of Environment has included an information pamphlet in the Anglers' Guide since 1993 and initiated a strategy in 2014 to curtail arrival of non-native mussels.

Analyses of public knowledge about non-native mussels were expected to help assess the successes and failures of these outreach efforts.

The matrix formatted AIS question section included the two mussels and a list of six invasive species found in the province. It consisted of a series of 16 ‘yes/no’ questions about: three fishes: common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), koi (domesticated ornamental varieties of *Cyprinus carpio*) three plants: flowering rush (*Butomus umbellatus*), purple loosestrife (*Lythrum salicaria*), salt cedar (*Tamarix ramosissima*, *Tamarix chinensis*, *Tamarix parviflora*), and two mussels. Eight questions asked respondents about their knowledge of presence or absence of a specific (fish, plant and mussel) organism and eight questions probed respondents about their knowledge of the negative impacts of each organism. Six questions asked about presence/absence and impact of fish organisms (common carp, goldfish and koi), six questions asked about presence/absence and impact of plant organisms (flowering rush, salt cedar, and purple loosestrife) and 4 asked about presence/absence and impact of mussel organisms (zebra mussels and quagga mussels). For knowledge of presence or absence of invasive species, we modelled each of the three outcome variables as the number of correct answers given per species for each type of organism (fish, plant and mussel) separately. We did the same for correct knowledge of negative impact of invasive species, separately for each type of organism. This lead to the construction of six separate outcome variables that conveyed information about the number of correct answers regarding knowledge of presence/absence and impacts of AIS by type of organism. From this information, we assessed participants’ knowledge of invasive species and used information from other relevant sections of the survey to identify trans-situational, situational and lake-related knowledge predictor variables associated with this knowledge.

We used univariate, bivariate and multivariate statistical techniques to define the composition of respondents and quantify the relationship between the various trans-situational, situational and lake-related knowledge variables, and the respondents' knowledge of AIS issues. Data processing, management and statistical analyses were conducted using IBM's Statistical Package for the Social Sciences (SPSS), Version 23. Univariate analyses provided descriptive statistics for all variables, including frequency distributions for awareness of the term 'invasive species', presence/absence, and impact of invasive species. Crosstab analyses with chi-square tests conducted for all three groups of organisms examined the relationship between correctly identifying presence/absence and the species' impacts. Regression analyses undertaken for each group of organisms assessed the influence of predictors on the outcome variables, namely presence/absence and impact of invasive species. Informed by the extant literature, our analyses also controlled for socio-demographic characteristics previously shown to influence these outcomes (e.g., Ansong and Pickering 2015; Bremner and Park 2007; Dean et al. 2016; Edwards et al. 2016; Eiswerth et al. 2011; García-Llorente et al. 2008; Heck et al. 2016; Pierce et al. 2010; Seekamp et al. 2016; Steel et al. 2005a), including respondent's sex, age, type of place of residence, ethnicity, education, and self-identified socio-economic status. The reviewed literature provided a reasonable basis for organizing these factors into a tentative conceptual model of knowledge of presence/absence and impact of AIS (Figure 2). The operational definition of the predictors considered in the analyses are presented in Appendix 2. Dummy coded variables were created for all categorical variables.

A series of regression analyses were performed to model the effects of the selected predictors on the six outcome variables. Stepwise variable selection procedure was applied to help select the "best" (most parsimonious) subset of predictors by removing redundant predictors, as unnecessary predictors add noise. The 95% significance level was used as a cut-off for statistically significant results. At each step, all eligible variables are considered for removal and entry till no more variables are eligible for inclusion or removal; thus, leading to more parsimonious models (Tabachnick and Fidell 2006). Because of the concern that linear regression is not always well-suited for analyzing these kinds of “limited dependent variables” (e.g., Cameron & Trivedi 2005; Long 1997, 2005; Wooldridge 2013), we also conducted count regression analyses (e.g., Poisson Regression, Negative Binomial Regression) to ensure our results are robust (results not reported here). Ultimately, we are presenting the results of the linear regression because there were no major differences in terms of statistical significance, direction of association, and model fitness in the findings by technique used, and multiple linear regression is a more intuitive model for an interdisciplinary audience to interpret and understand. We also examined frequency distributions of zebra and quagga mussel awareness (yes/no), and conducted forward conditional stepwise logistic regression analyses to identify significant predictors of mussel awareness.

The AIS question section also included open-ended questions probing respondents to explain the cleaning procedure for a boat with mussels on it and to identify who they would contact if mussels were discovered on a boat. Content analysis was used to categorise the respondents’ answers to these questions (Neuman and Robson 2011). For this analysis, we examined common themes about contaminated boat cleaning procedures (‘clean, drain, dry’) and who to contact (SK Ministry of Environment TIP ‘Turn In Poachers’ line) in the event of discovering mussels on a boat. Additionally, answers were scrutinized for a clear indication of knowledge about the need to 1) clean a contaminated boat using high pressure, hot tap water (50°C) thoroughly scrubbing and rinsing surfaces; 2) drain all onboard water (including motor, livewell, bilge and bait buckets); and 3) dry contaminated boat and all gear for five days in the hot sun (if unable to rinse). Answers to this question were categorized as correct, incorrect or partially correct (if the answer contained some aspect of ‘clean, drain and dry’).

Results

A total of 476 participants filled out the survey questionnaire. Overall, the online option was more widely used than the in-person paper survey. We received 427 survey submissions online while only 49 opted to fill out the paper copy on-site. A comparison of the demographic characteristics of survey respondents to the general Saskatchewan population revealed that in our sample, only 4.6% of respondents identified as First Nations compared to 15.6% of the SK population identified as First Nations in the National Household Survey (Statistics Canada 2011). Unfortunately, additional outreach efforts in January and February 2016 did not significantly increase First Nations recruitment in the survey and these communities remain underrepresented.

Many participants visited lakes in at least two geographic regions in the province (44.3%, n = 211), and single-region visitors were most common on lakes along the west-to-east draining Qu’Appelle River catchment (20.6%, n = 98) (Appendix 3). Overall, lakes were used mostly for fishing, swimming, boating, and recreation (activities other than fishing and swimming) purposes, with some differences between regions in terms of lake-use purpose (Appendix 4). A total of 36 respondents (7.6%) did not use lakes in Saskatchewan and were excluded from subsequent analyses.

Most respondents were aware of the term ‘invasive species’ (92.4%). Many were also aware of presence of carp in SK waters (79.5%) and about half were aware of purple loosestrife (51.1%), but most respondents were unaware of the presence of goldfish (58.0%), koi (58.5%), flowering rush (88.4%) and salt cedar (93.7%) (Table 1). Additionally, many participants were unaware that zebra (72.6%) and quagga (76.0%) mussels had not yet colonized waterways in the province (Table 1). Only about 33% of respondents had heard about quagga mussels, but a majority of respondents (86.7%) had heard about zebra mussels (Appendix 5). Many (80.3% zebra mussels and 58.3% quagga mussels) participants were, however, aware of the negative impacts of exotic mussels (Table 1). In contrast, most respondents were unaware of the potential negative impact of flowering rush and salt cedar on native ecosystems, and only half of them had an understanding of the potential negative impacts of goldfish (Table 1). Crosstabulations with chi-square tests yielded significant ($p<0.001$) positive relationships between correctly identifying presence/absence of a given organism and correctly identifying negative impact of that organism for all three groups (Table 2).

Regression analyses identified the importance of trans-situational, situational and lake-related knowledge predictors associated with correctly identifying presence/absence (Table 3, *see also* Figure 3) and impacts of AIS in southern Saskatchewan (Table 4, *see also* Figure 4). Specifically, fishing and awareness of lake-related environmental issues (eutrophication, winterkill, and industrial water extraction) were positively and significantly related to correctly identifying the presence of fishes. Age, rural residence (compared to residence in medium or large cities), swimming, and recreation were all negatively associated with correctly identifying the presence of fishes. In contrast, older participants, and those who used all three lake regions, or used lakes for work, and aware of eutrophication were more likely to be knowledgeable of presence of listed plants. Similarly, using all three lake regions, using lakes for work and awareness of eutrophication were positively and significantly related to correctly identifying absence of invasive mussels in SK waters. Awareness of eutrophication was a significant predictor of presence/absence knowledge for all three groups of organisms (Table 3, Figure 2).

More educated respondents and fishers were more knowledgeable about the negative impacts of all AIS (Table 4, Figure 3). Males and those aware of industrial water extractions were more knowledgeable of the negative impact of invasive fishes, whereas age was inversely related to awareness of negative impact of invasive fishes. In turn, those aware of both eutrophication and water extraction were more likely to correctly identify negative impact of plants. Swimmers, on the other hand, were significantly less likely to be familiar with negative impacts of both plants and mussels. Male respondents using all three lake regions, and those aware of eutrophication were more knowledgeable about impacts of mussels. Awareness of eutrophication increased the likelihood of having heard about both zebra and quagga mussels (Table 5). Additionally, better educated, older males were more likely to have heard about zebra mussels and those using lakes for work were more likely to have heard about quagga mussels, while respondents using lakes for seasonal cabins were less likely to have heard about quagga mussels.

Only 5.7% of participants correctly answered ‘clean, drain, dry’ as the best method to prevent a mussel invasion, whereas 61.1% were aware of at least one step, and one-third (33.2%) were completely unaware of recommended cleaning processes. Among those who correctly identified the need to dry the infected boat, there was no consensus on length of drying time, with responses ranging from 72 hours to 90 days to ‘let it freeze over winter’. Similarly, participants aware of the need to clean the boat did not identify a uniform protocol, with answers including using household bleach, domestic cleaning substances, vinegar, muriatic acid, chlorine, disinfectant, chemical treatments, poisons, acid-based cleaners, dish washing detergent, bug killer and pesticides. Regarding who to contact in the event of mussel discovery, only 4.4% correctly stated the SK government TIP telephone line, while 72.1% stated various levels of government, ranging from the local municipality’s office, to the local Conservation Officer, specific provincial ministries, federal agencies (e.g., Environment Canada, Fisheries and Oceans Canada), or the Royal Canadian Mounted Police (RCMP), a federal law enforcement agency in Canada. Almost a quarter (23.5%) of participants did not know who to contact or simply would not contact any authority if mussels were found.

Discussion

Our study highlights the dynamic nature of AIS knowledge among stakeholders. Findings suggest that current outreach and communication methods are either ineffective at reaching desired audiences or important information is not being retained, or a combination of the two. As noted elsewhere (Dean et al. 2016; Eiswerth et al. 2011; Steel et al. 2005a; Steel et al. 2005b), the regression analyses identified trans-situational (e.g., age, sex, education), situational (e.g., mode and location of recreation) and lake-related knowledge (e.g., eutrophication) predictors. Consistent with prior analyses of AIS knowledge across organisms (Lindgren 2006; Strayer 2009), respondents were more aware of effects and presence of invasive fishes than plants. Surprisingly, substantial knowledge gaps were identified concerning the presence and prevention of non-native mussel transmission. In our study, awareness of eutrophication was found to be a simple but near-universal predictor of respondent's knowledge concerning AIS, while previous studies identified breadth and depth of recreational involvement as near-universal predictors (Eiswerth et al. 2011; Seekamp et al. 2016). Therefore, our study provides further evidence for the overall importance of lake-based activities and lake-related knowledge as determinants of AIS knowledge. Based on our results, we propose that future management strategies focus on improving communications by streamlining outreach messages, targeting low-knowledge groups (e.g., swimmers, cabin owners), and expanding education campaigns.

Aquatic invasive fish vs. plant species

Although most respondents were aware of the term ‘invasive species’, knowledge about presence/absence and impacts of AIS was organism-dependent. Overall knowledge of invasive fishes was greater than that of invasive plants. This observation may be an extension of the general bias towards an increased interest in animals over plants (Martín-López et al. 2007). It may also be a reflection on the regulation of non-native animals (Ministry of Environment) and plants (Ministry of Agriculture) by separate ministries with different communications strategies (Provincial Auditor 2016). Relatively high knowledge about presence and impacts of carp may be attributed to attention in the media, its inclusion in the annual Anglers’ Guide, and the presence of a commercial fishery that was operational until the 1980’s. In contrast, goldfish are often purchased as pets and koi are ornamental species, thus, familiarity with them in these contexts may limit concern over their environmental impacts relative to carp (Lindemann-Matthies 2016; Shackleton and Shackleton 2016; Touza et al. 2014). Comparable to findings in neighboring Manitoba (Lindgren 2006), most respondents did not know about the presence or negative impacts of invasive plants such as flowering rush and salt cedar. However, similar to Lindgren (2006), many respondents correctly identified presence and negative impact of purple loosestrife. In this instance increased familiarity may be attributed to its identification and description as an aquatic invasive plant on the Government of SK (Ministry of Environment) website.

Mussels

As shown in previous studies (Strayer 2009), respondents exhibited variable knowledge about invasive mussels. Despite low awareness of mussel absence in SK, many respondents correctly identified the negative impact of both invasive mussels, which may be attributed to the high visibility of mussels through widespread media coverage in North America (Haag and

Williams 2014; Strayer 2009). Results on mussel presence/absence should be of concern to managers, government, stakeholders and scientists alike because if non-expert stakeholders incorrectly assume SK waters have already been invaded by mussels or are unaware of their status in the province, they may be less inclined to engage in preventative and/or control behaviors, as seen elsewhere (Drake et al. 2015; Gates et al. 2009).

Inconsistent nature of the answers to the open-ended questions provides evidence that current outreach efforts are either not delivering the message in a clear, understandable manner or that it is not being retained. The message of ‘clean, drain, dry’ is a central tenant of invasive mussel prevention and control campaigns around the world (Gates 2009; Seekamp et al. 2016; Zook and Phillips 2012), and needs to be delivered successfully to recreationists utilizing water-crafts to prevent mussel invasion. Even when water-craft users are willing to drain their boats, they are unlikely to use a hot water rinse as recommended (Connelly et al. 2016; Seekamp et al. 2016). Therefore, such a program needs to include better transmission of information on precise protocols, as most respondents did not know the length of time a watercraft should be dried, or the cleaning procedures needed to ensure adult mussels and veligers are completely removed from contaminated boats and equipment. Of added concern is the predisposition of some respondents to clean watercrafts with chemicals (only hot water is recommended in the protocol) that are not only harmful to waterways but also to individuals themselves. Additionally, outreach material should prominently display relevant contact information and emphasize the need to contact authorities via the TIP line if watercraft is contaminated with mussels.

Role of predictors

As organized in Figure 1, this study explored the impact of a number of trans-situational, situational, and lake-related knowledge factors related to AIS knowledge. Consistent with previous studies, certain trans-situational variables were important predictors of invasive species knowledge. While increased respondent age is generally associated with higher levels of environmental awareness (Lindgren 2006; Steel et al. 2005a), the relationship between age and knowledge in our study was less straightforward. We are unsure about the exact causes behind the heterogeneity (negatively associated with fishes but positively associated with plants) of the influence of age on AIS knowledge. The positive influence of age on environmental awareness is partly attributed to the accumulated impact of exposure to environmental information since the 1960s environmental awareness movement (Otto and Kaiser 2014). Even though past empirical research indicates that the relationship between sex and environmental awareness is complicated (Harvey et al. 2016; Otto and Kaiser 2014), males in our study were generally more knowledgeable about invasive fish impacts, more aware of zebra mussels' colonization patterns, and more informed of mussel impacts on the environment. Consistent with the observation that level of formal education is an important predictor of AIS awareness (Eiswerth et al. 2011), we noted that education was associated positively with increased knowledge of negative impacts of fishes, plants and mussels. Finally, residential location was an important predictor of AIS issues, as rural residents were less likely to be knowledgeable about fish presence than urban participants. These "non-modifiable" predictors are more static compared to contextually impressionable situational and knowledge predictors (Steel et al. 2005a) and therefore, management efforts should prioritize situational predictors and focus less on trans-situational variables.

In our study, we identified several key situational factors. Fishing was an important predictor of AIS knowledge. This effect is generally attributed to fishers increased familiarity with invasive outreach information and campaigns, better developed sense of personal responsibility to control AIS, and engagement in preventive behaviors (Edwards et al. 2016; Eiswerth et al. 2011; Seekamp et al. 2016). Higher knowledge of the presence of plants and absence of mussels and their negative impacts among respondents who used all three lake regions and used lakes for work may be due to repeated interactions with lake environments. Such interactions often result in more positive experiences with that environment, increase environmental concern and acts as a situational motivator to promote knowledge-seeking behavior (Eiswerth et al. 2011; Steel et al. 2005a; Steel et al. 2005b).

Not all situational predictors were positively correlated with increased understanding of AIS issues. For example, use of lakes for recreational swimming was associated negatively with knowledge of fish presence, and impacts of both plants and mussels. Similar to Strayer's (2009) findings, recreationists (non-fishing/non-swimming) were also generally less knowledgeable about the presence of invasive fish organisms. Additionally, cabin-use was related negatively to awareness of quagga mussels. Possibly, recreationists and cabin owners are more concerned about other well-publicized threats to their lakes (e.g., eutrophication, industrial water extraction, pesticide exposure, etc.) (Eiswerth et al. 2011). Low knowledge among cabin-users may also be attributed to the highly seasonal nature of cabin use in SK, which may limit cabin owners' contact with lake-relevant information, including AIS.

In addition to trans-situational and situational predictors of AIS knowledge, knowledge of lake-related environmental issues increased understanding of AIS-related issues. In particular, awareness of eutrophication was a near-universal predictor of AIS for both presence/absence and impact. Noxious summer algal blooms have been reported in southern Saskatchewan since the early 20th century (Rawson and Moore 1944), and have become a well-publicized water quality issue that has resulted in upgrades (> CAD $200 million) to the City of Regina wastewater treatment plant (CCPPP 2014). Similarly, industrial water extractions from Qu'Appelle Valley lakes have been prominent in the media for over five years (WSA 2012), possibly explaining its linkage to knowledge of AIS-related topics (fish presence, fish impacts and plant impacts). Likely, exposure to lake-related environmental issues such as eutrophication or industrial water extraction has engendered greater overall knowledge about lakes through stimulation of knowledge-seeking behavior, as seen elsewhere (Dean et al. 2016; Steel et al. 2005a; Steel et al. 2005b).

Management implications

Low levels of AIS knowledge recorded across all organisms indicate a need to critically evaluate current outreach and communication efforts. Our findings echo results from an earlier survey (Koob and McGuire 2013) that outreach campaigns are not effectively reaching the desired audience. Many factors may contribute to reduced effectiveness, including: stakeholders inability to recall campaign messages (Seekamp et al. 2016); public preference for new or non-traditional media (e.g., Twitter, Facebook) not employed by managers (Koob and McGuire 2013); messages are convoluted or overly-complex (technical) (Seekamp et al. 2016); strategies place insufficient emphasis on personal responsibility and potential damages (Drake et al. 2015; Seekamp et al. 2016; Strayer 2009) and; unreceptive or inattentive stakeholders (Drake et al. 2015). We recommend a focus group methodology that includes a variety of stakeholders to help identify mechanisms responsible for campaign ineffectiveness and how strategies should be modified to enhance message retention and recall. A dual outreach portfolio may be particularly effective, with education and outreach campaigns expanded province-wide, utilizing multiple social media formats (blogs, Twitter, Facebook) in addition to more traditional media avenues (television, radio, print), while also directly providing critical information at each lake to increase awareness of AIS. In particular, we suggest that campaign developers and implementers be cognizant of the need to keep the AIS information direct, concise, and jargon-free (Shu and Carlson 2014). We also recommend careful study of similar campaigns underway in comparable regions to determine their effectiveness before implementation.

Along with expansion of education and communication strategies, managers should target the use of situational information identified from the findings of the present study to increase knowledge levels in individual groups. For example, to capitalize on the positive relationship between multiple-lake use and AIS knowledge, the province could use tourist advertising or competitions to encourage stakeholders to visit many lakes. Targeting information at non-fishing/boating recreationists may be more effective in improving general understanding than primarily posting information boards at fishing sites. It is important to draw connections between recreationists desired lake-related activity and the impact of AIS. For example, bird-watchers should be informed about potential decreases in food, shelter and nesting areas due to purple loosestrife encroachment. Similarly, cabin-owners could be educated about detrimental impacts of mussels on their personal infrastructure (water intake pipes, swimming) and property values to address the inverse relationship between cabining and quagga mussel awareness. While recreationists and cabin-users may not be direct vectors of AIS dispersal, increased engagement by this group may help apply pressure to boat-owning or fishing neighbors to be more attentive to AIS transmission. In particular, the strong positive association between lake-relevant knowledge and AIS knowledge illustrates benefits of increasing ‘lake-literacy’ among general stakeholders. More knowledgeable citizens are also more likely to support AIS management efforts and engage in more responsible behaviors (Reed 2008; White and Ward 2010).

Based on our findings that stakeholders are poorly informed about the status of exotic mussels in SK and the province's vulnerability to a mussel invasion, managers should develop a long-term, multi-party AIS strategy focused on prevention (Leung et al. 2002; Lovell et al. 2006; Sharp et al. 2016), early detection, and eradication (Vander Zanden et al. 2010). Invasive mussels are now established in most regions surrounding SK, particularly at sites such as Lake Winnipeg, which are directly linked to the Qu'Appelle drainage by river flow. Poor knowledge about mussel presence, combined with uneven understanding of effective preventive behaviors, makes the province especially vulnerable to invasive mussels along east-west corridors. Therefore, we propose the development of a multi-stakeholder coalition between universities, lake associations, fishing tournaments, recreation organizations and citizen science groups to help prevent mussel contaminated watercrafts entering the province. Such a coalition may also alleviate resource burdens and provide more buy-in for stakeholders. For example, once potential invasion corridors are identified, industrial partners may be willing to provide necessary funding to construct watercraft wash-stations, and well-trained community volunteers may be willing to operate such stations.

Conclusions

Studies such as ours help understand important knowledge gaps about effectiveness of invasive species outreach campaigns (Strayer 2009). Given the global significance of invasive species in both aquatic and terrestrial environments, application of methods used and insights gained from our study are not limited to prairie lakes. We found that public perceptions of AIS were organism-dependent, emphasizing the importance of addressing invasive species issues on a context-specific basis. Results also highlight the need for a multi-stakeholder approach to rectify low AIS knowledge. In particular, we feel it may be important to quantify knowledge levels at the onset of the decision-making process, involve diverse stakeholders, and continue knowledge assessments at regular intervals. A survey instrument similar to ours will help assess baseline invasive species knowledge and evaluate effectiveness of outreach efforts. Results from such a survey will be particularly applicable if questions are sourced (in part) from managers and practitioners (Matzek et al. 2014). Assessing and understanding public knowledge about environmental issues can be an invaluable tool that helps prioritize education, outreach and management goals which may ultimately facilitate adoption of desired environmental behaviors. Additionally, increased AIS knowledge may have a ‘spill-over’ effect and positively impact knowledge seeking behavior about other issues (e.g., overfishing, industrial pollution) that affect lakes, increasing overall ‘lake literacy’ levels. More knowledgeable citizens will, in turn, be able to better engage in management decisions that impact the health of lakes.

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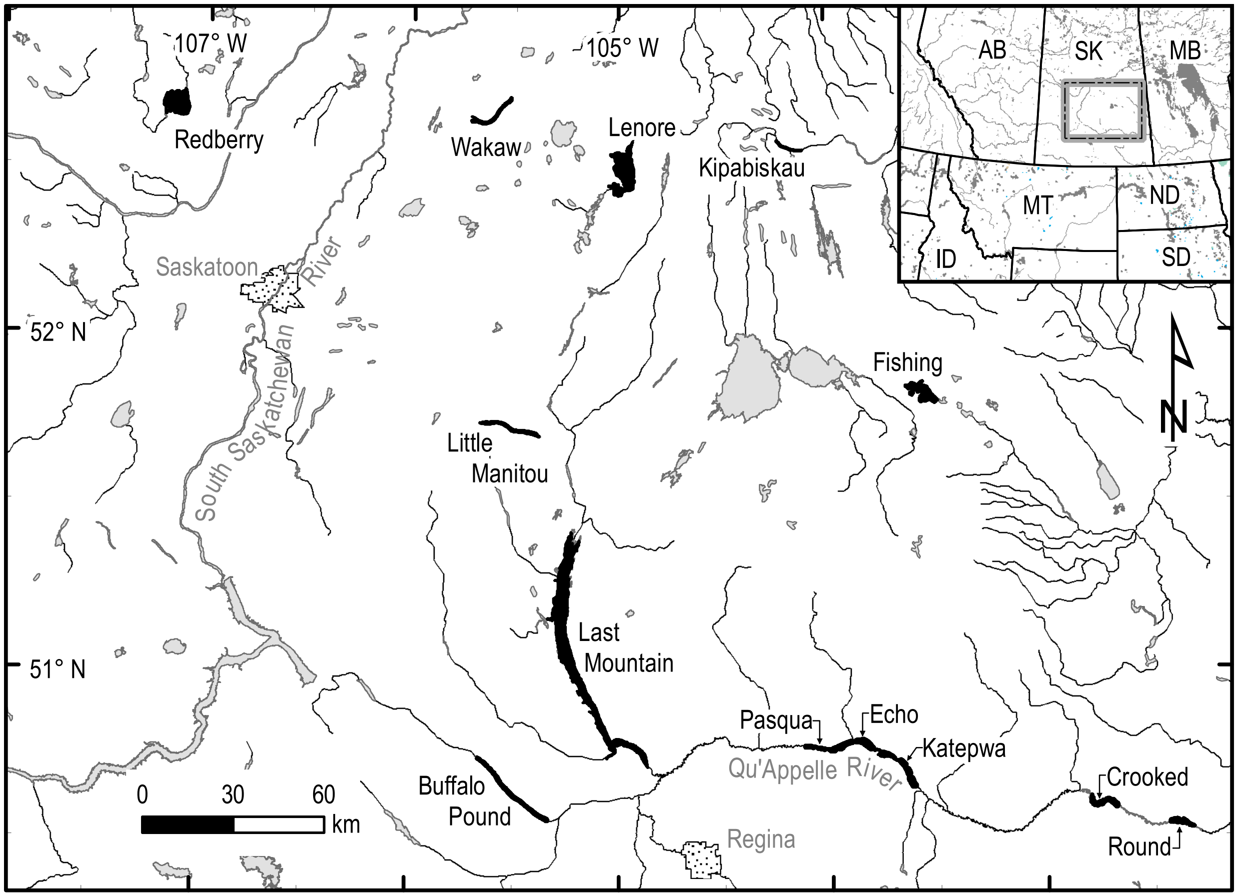
Figure 1. Map of study lakes in Saskatchewan, Canada. Inset identifies the location of the study area within the province. The Qu'Appelle River catchment consists of the following lakes: Pasqua, Echo, Katepwa, Crooked and Round. Surveys were distributed at Redberry, Wakaw, Lenore, Kipabiskau, Little Manitou, Fishing, Buffalo Pound, Last Mountain, and Echo lakes. Regina and Saskatoon are the major urban centers in Saskatchewan.



107° W
105° W
Redberry
Wakaw
Lenore
Kipabiskau
AB
SK
MB
MT
ND
ID
SD
Saskatoon
South Saskatchewan River
52° N
Fishing
Little Manitou
Last Mountain
51° N
Pasqua
Echo
Katepwa
Qu'Appelle River
Crooked
Round
Buffalo Pound
Regina
0
30
60
km
N

Figure 2. Conceptual framework of influence of trans-situational, situational, and lake-related knowledge predictors on presence/absence and impact of AIS

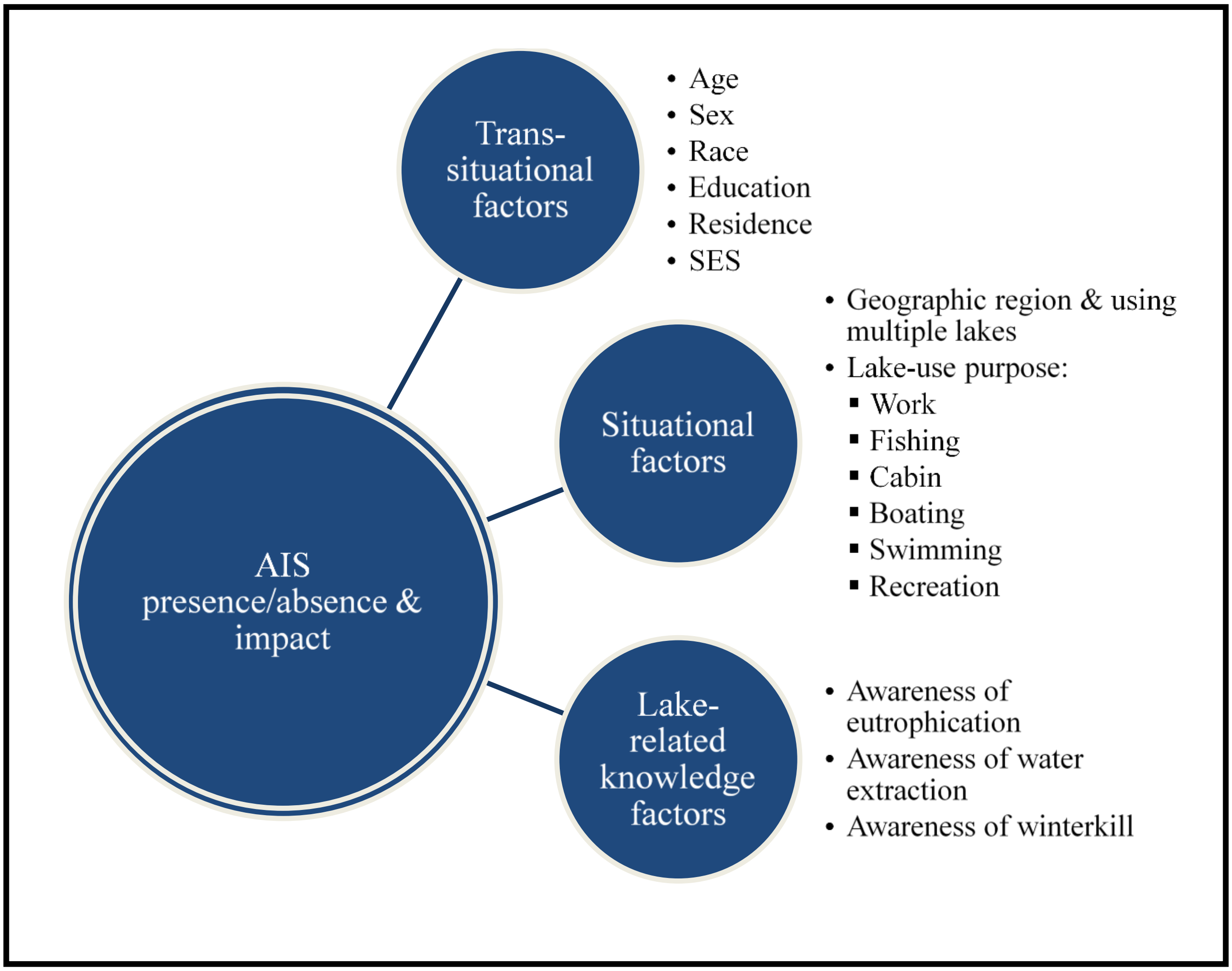


Table 1. Presence/absence and impact knowledge for each species, PLUMS 2015-2016

Species	Presence/absence			Impact		
	Present	Absent	Don't know	Positive	Negative	Don't know
Carp	79.5% (*n* = 333)	3.3% (*n* = 14)	17.2% (*n* = 72)	12.8% (*n* = 52)	61.5% (*n* = 249)	25.7% (*n* = 104)
Goldfish	42.0% (*n* = 170)	18.7% (*n* = 76)	39.3% (*n* = 159)	4% (*n* = 15)	50.5% (*n* = 192)	45.5% (*n* = 173)
Koi	41.5% (*n* = 169)	13.5% (*n* = 55)	45.0% (*n* = 183)	2.9% (*n* = 11)	53.1% (*n* = 199)	44.0% (*n* = 165)
Flowering Rush	11.6% (*n* = 46)	12.2% (*n* = 48)	76.2% (*n* = 301)	1.1% (*n* = 4)	34.8% (*n* = 126)	64.1% (*n* = 232)
Salt Cedar	6.3% (*n* = 25)	14% (*n* = 55)	79.7% (*n* = 315)	0.8% (*n* = 3)	31.1% (*n* = 110)	68.1% (*n* = 241)
Purple Loosestrife	51.1% (*n* = 206)	7.5% (*n* = 30)	41.4% (*n* = 167)	3.7% (*n* = 14)	62.3% (*n* = 236)	34.0% (*n* = 129)
Zebra mussels	36.3% (*n* = 151)	27.4% (*n* = 114)	36.3% (*n* = 151)	3.3% (*n* = 13)	80.3% (*n* = 314)	16.4% (*n* = 64)
Quagga mussels	14.7% (*n* = 60)	24.0% (*n* = 98)	61.3% (*n* = 250)	1.9% (*n* = 7)	58.3% (*n* = 218)	39.8% (*n* = 149)

Note. Valid percent (%, first row) and frequency (*n*, second row). All fishes and plants are present in SK, mussels are absent. All AIS listed are associated with negative impacts.

Table 2. Crosstabulations with chi-square tests for associations between correctly identifying presence/absence of a group of AIS and correctly identifying their negative impacts, PLUMS 2015-2016

	Correctly identified presence/absence (%)				
Impact	**None**	**One organism**	**Two organisms**	**Three organisms**	**Chi-square**
Fishes					170.684*
None correct	70.0	31.4	24.4	10.8	
One correct	10.0	41.5	16.7	8.1	
Two correct	–	8.2	30.0	21.6	
Three correct	20.0	18.9	28.9	59.5	
Plants					295.439*
None correct	76.3	13.6	8.8		
One correct	4.6	57.4	14.7	9.1	
Two correct	1.4	8.0	41.2	9.1	
Three correct	17.8	21.0	35.3	81.8	
Mussels					52.816*
None correct	34.4	8.7	16.9	N/A	
One correct	23.8	43.5	4.8	N/A	
Two correct	41.8	47.8	78.3	N/A	

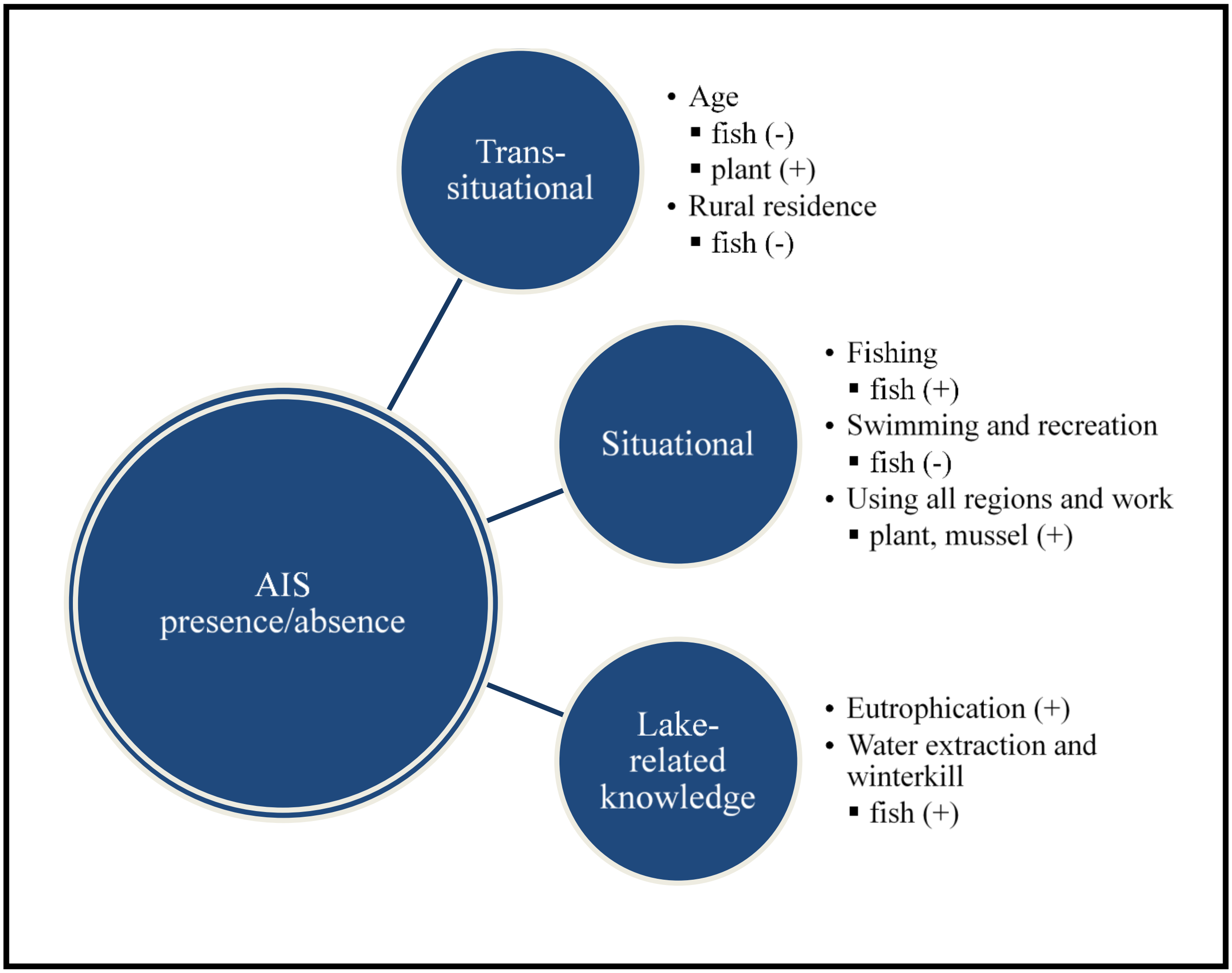
Note. *p<0.001

Table 3. Stepwise multiple linear regression for predictor variables associated with correctly identifying presence/absence of fish, plant and mussel organisms, PLUMS 2015-2016

	Correctly identifying presence/absence of:											
	Fish Organisms				Plant Organisms				Mussel Organisms			
Predictor Variables	**B**	**Beta**	**Sig.**	**Model Entry**	**B**	**Beta**	**Sig.**	**Model Entry**	**B**	**Beta**	**Sig.**	**Model Entry**
(Constant)	1.775		0.000		0.044		0.757		0.320		0.000	
Age	-0.011	-0.152	0.003	5	0.008	0.159	0.003	3	–	–	–	–
City/Town/RM of Residence[1]												
Rural area	-0.343	-0.152	0.002	4	–	–	–	–	–	–	–	–
Small population center	–	–	–	–	–	–	–	–	–	–	–	–
Lakes' Region[2]												
South of Diefenbaker Qu'Appelle	–	–	–	–	–	–	–	–	–	–	–	–
North of Diefenbaker Qu'Appelle	–	–	–	–	–	–	–	–	–	–	–	–
Two different lake regions were used	–	–	–	–	–	–	–	–	–	–	–	–
All three lake regions were used	–	–	–	–	0.228	0.122	0.020	4	0.213	0.108	0.038	3
Purpose: Fishing	0.344	0.141	0.005	2	–	–	–	–	–	–	–	–
Purpose: Swimming	-0.332	-0.145	0.006	3	–	–	–	–	–	–	–	–
Purpose: Work	–	–	–	–	0.468	0.183	0.000	2	0.372	0.138	0.011	2
Purpose: Recreation	-0.250	-0.113	0.031	8	–	–	–	–	–	–	–	–
Awareness of Eutrophication	0.276	0.126	0.013	1	0.407	0.259	0.000	1	0.252	0.152	0.004	1
Awareness of Winterkill	0.310	0.111	0.028	6	–	–	–	–	–	–	–	–
Awareness of Water Extraction	0.266	0.112	0.026	7	–	–	–	–	–	–	–	–
R	**0.453**				**0.379**				**0.272**			
R square	**0.206**				**0.144**				**0.074**			

Note. [1]Reference category = Medium-to-large population center: population of 30,000 or more; [2] Reference category = Diefenbaker – Qu'Appelle system; (−) = Predictor variable did not enter the model. In each model, we entered the following predictors: respondent's sex, age, race, highest educational level, self-perceived SES, city/town/RM of residence, lake's region, purpose: fishing, purpose: swimming, purpose: boating, purpose: recreation, purpose: work, purpose: cabining, awareness of eutrophication, awareness of winterkill and awareness of water extraction. Dummy coded variables (no. of categories -1) were created for categorical predictors.

Figure 3. Findings-based layout of the impact of trans-situational, situational, and lake-related knowledge predictors on presence/absence of AIS



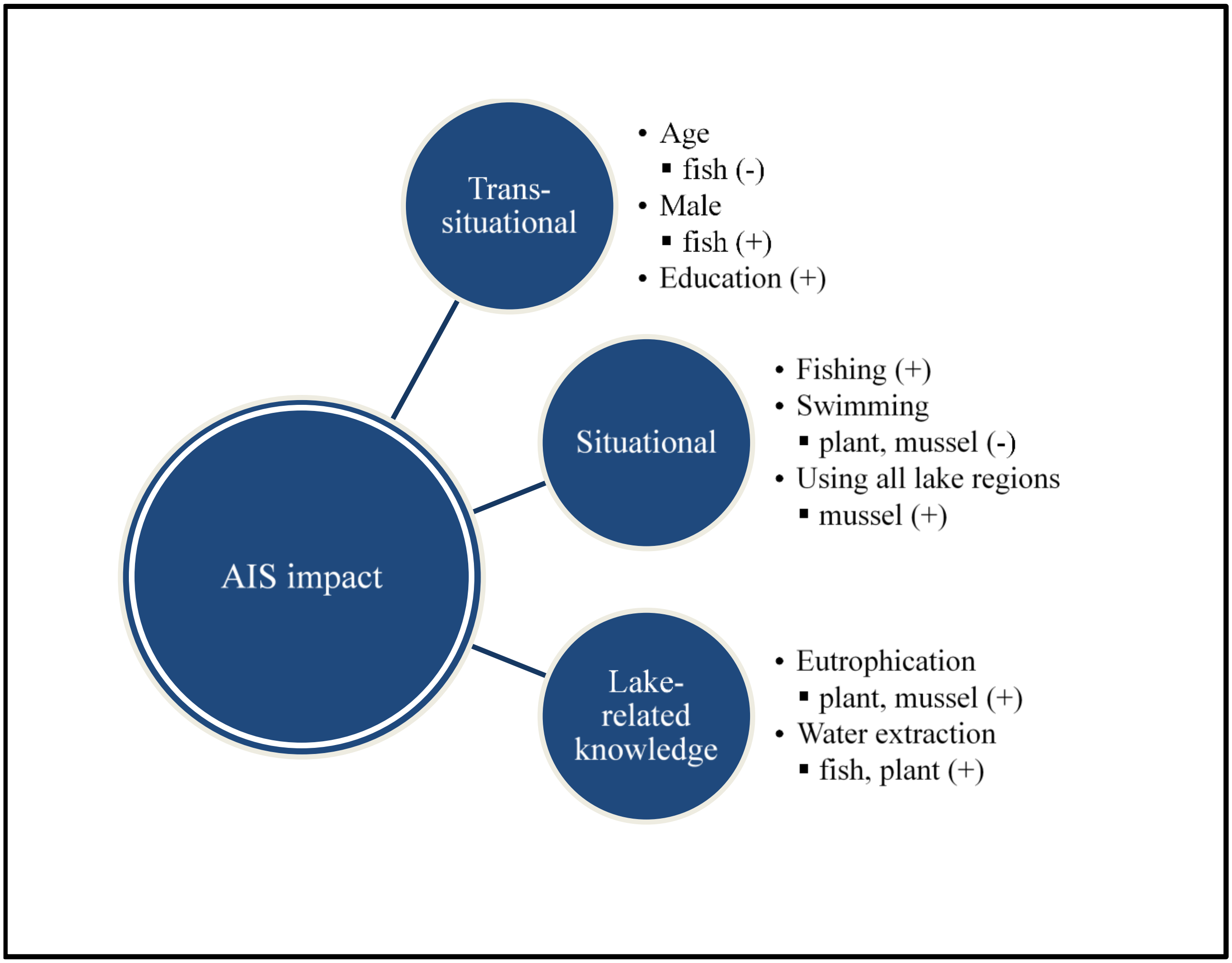
Note. Unless otherwise specified, the predictor impacts all three groups (fish, pant, mussel) of organisms. (+) and (-) indicates the direction of the relationship. For example, older respondents are less knowledgeable about presence of non-native fishes but more knowledgeable about plants.

Table 4. Stepwise multiple linear regression for predictor variables associated with correctly identifying negative impact of fish, plant and mussel organisms, PLUMS 2015-2016

	Correctly identifying negative impact of:											
	Fish Organisms				**Plant Organisms**				**Mussels Organisms**			
	B	**Beta**	**Sig.**	**Model Entry**	**B**	**Beta**	**Sig.**	**Model Entry**	**B**	**Beta**	**Sig.**	**Model Entry**
(Constant)	0.540		0.090		0.138		0.579		0.493		0.005	
Age	-0.013	-0.156	0.002	3	–	–	–	–	–	–	–	–
Male[1]	0.441	0.160	0.002	4	–	–	–	–	0.373	0.197	0.000	1
Highest Level of Education	0.128	0.142	0.005	5	0.111	0.126	0.018	4	0.082	0.131	0.011	5
Lakes' Region[2]												
South of Diefenbaker Qu'Appelle	–	–	–	–	–	–	–	–	–	–	–	–
North of Diefenbaker Qu'Appelle	–	–	–	–	–	–	–	–	–	–	–	–
Two different lake regions were used	–	–	–	–	–	–	–	–	–	–	–	–
All three lake regions were used	–	–	–	–	–	–	–	–	0.309	0.147	0.003	3
Purpose: Fishing	0.583	0.203	0.000	1	0.506	0.181	0.000	2	0.211	0.106	0.038	6
Purpose: Swimming	–	–	–	–	-0.307	-0.117	0.022	5	-0.241	-0.130	0.010	4
Awareness of Eutrophication	–	–	–	–	0.276	0.110	0.038	1	0.234	0.132	0.011	2
Awareness of Water Extraction	0.389	0.139	0.007	2	0.324	0.119	0.023	3	–	–	–	–
R	**0.399**				**0.319**				**0.388**			
R square	**0.159**				**0.102**				**0.151**			

Note.[1]Reference category = Female; [2]Reference category = Diefenbaker – Qu'Appelle system; (−) = Predictor variable did not enter the model. In each model, we entered the following predictors: respondent's sex, age, race, highest educational level, self-perceived SES, city/town/RM of residence, lake's region, purpose: fishing, purpose: swimming, purpose: boating, purpose: recreation, purpose: work, purpose: cabining, awareness of eutrophication, awareness of winterkill and awareness of water extraction. Dummy coded variables (no. of categories -1) were created for categorical predictors.

Figure 4. Findings-based layout of the impact of trans-situational, situational, and lake-related knowledge predictors on negative impact of AIS



Note. Unless otherwise specified, the predictor impacts all three groups (fish, pant, mussel) of organisms. (+) and (-) indicates the direction of the relationship. For example, older respondents are less knowledgeable about the impact of non-native fishes.

Table 5. Forward conditional stepwise logistic regression of awareness of zebra and quagga mussels, PLUMS 2015-2016

	Have you heard about:							
	Zebra Mussels				Quagga Mussels			
	B	Sig.	Exp(B)	Model Entry	B	Sig.	Exp(B)	Model Entry
(Constant)	-2.259	0.012	0.104		-1.057	0.000	0.347	
Age	0.025	0.039	1.025	5	–	–	–	–
Male[1]	1.804	0.000	6.074	1	–	–	–	–
Highest Level of Education	0.465	0.001	1.591	2	–	–	–	–
Purpose: Swimming	-0.909	0.052	0.403	6	–	–	–	–
Purpose: Work	–	–	–	–	1.649	0.000	5.201	1
Purpose: Cabining	–	–	–	–	-0.495	0.051	0.610	3
Awareness of Eutrophication	1.417	0.009	4.124	4	0.982	0.000	2.670	2
Awareness of Winterkill	0.690	0.086	1.993	3	–	–	–	–
-2 Log likelihood	**214.860**				**409.776**			
Nagelkerke R Square	**0.329**				**0.168**			

Note. [1]Reference category = Female; (−) = Predictor variable did not enter the model. In each model, we entered the following predictors: respondent's sex, age, race, highest educational level, self-perceived SES, city/town/RM of residence, lake's region, purpose: fishing, purpose: swimming, purpose: boating, purpose: recreation, purpose: work, purpose: cabining, awareness of eutrophication, awareness of winterkill and awareness of water extraction. Dummy coded variables (no. of categories -1) were created for categorical predictors.

APPENDIX
TABLES 1-5

Appendix 1. Operational definitions and explanations of concepts in ‘invasive species’, PLUMS 2015-2016

Concept and Explanation
I. Species
• List of eight invasive species. • Three fish**es***: common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), and koi (domesticated ornamental varieties of *Cyprinus carpio*). • Three plant**s***: flowering rush (*Butomus umbellatus*), salt cedar (*Tamarix ramosissima, Tamarix chinensis, Tamarix parviflora*), and purple loosestrife (*Lythrum salicaria*). • Two mussels: zebra mussels (*Dreissena polymorpha*), and quagga mussels (*Dreissena bugensis*).
II. Presence/Absence
• All fish and plant organisms present, and mussels absent in Saskatchewan at the time surveys were administered. • Assessed using “yes/no/don’t know” answers to inquiry about awareness of presence/absence of organism.
III. Impact
• Organisms listed in the survey have negative impacts on invaded aquatic ecosystems. • Assessed using “positive/negative/don’t know” answers to inquiry about impact of organisms. Increased water clarity due to mussel presence is an example of a positive impact while decreased biodiversity and habitat loss are examples of negative impacts.
IV. Mussels
• Zebra and quagga mussels are particularly destructive invasive species with far reaching consequences on invaded habitats and regional economies. Therefore, success/failure of government outreach efforts to increase public knowledge of mussels was assessed using yes/no answers to inquiry about awareness of two mussels.
V. Open-ended Questions
• How to clean a contaminated boat, inquired about procedure to clean a boat contaminated with zebra or quagga mussels. • Who to contact, inquired about who should be contacted if mussels are discovered on boat.

Note. *List of organisms was provided by the Saskatchewan Ministry of Environment.

Appendix 2. Operational definitions of predictor variables considered in the regression analyses, PLUMS 2015-2016

Variable Label and Explanation

I. Socio-Demographic Factors

- *Sex*, a discrete, nominal variable. Female is the reference category.
- *Age*, a continuous, interval/ratio variable that inquired about age at time of survey.
- *Residence*, self-reported variable that indicates town/city/rural municipality of residence at time of survey. Medium-to-large population center – population of 30,000 or more is the reference category.
- *Race*, a discrete, nominal variable (White vs. Others). Other is the reference category.
- *Level of Education*, self-reported variable that indicates highest level of education at time of survey.
- *Socio-economic status* (SES), reported as self-perceived value on a five-point Likert scale item (1 = “low SES” and 5 = “high SES”).

II. Situational/Contextual Factors

- *Geographic region*, three, separate questions that inquired about lake-use in each of all three regions. These were combined into one variable, containing the following responses: A_Diefenbaker – Qu’Appelle system; B_South Diefenbaker QuAppelle; C_North Diefenbaker QuAppelle; Two different lake regions were used; and All three lake regions were used. Diefenbaker – Qu’Appelle system is the reference category.
- *Lake-use purpose*, seven, separate “yes/no” items that inquired about purposes of lake-use by geographic region.

III. Knowledge Factors

- *Eutrophication* (“yes/no”), refers to increased algal production due to increased nutrient inputs from watershed.
- *Winterkill* (“yes/no”), refers to increased fish mortality over winter due to increased biological oxygen demand (especially in eutrophic lakes).
- *Extraction* (“yes/no”), refers to extraction of water from lakes for industrial, agricultural and municipal purposes.

Appendix 3. Frequency and percent of lake-use by region, PLUMS 2015-2016

Region	Frequency	Percentage (%)
None	36	7.6
Diefenbaker – Qu'Appelle	98	20.6
South of Diefenbaker – Qu'Appelle	64	13.4
North of Diefenbaker – Qu'Appelle	67	14.1
Two lake regions	129	27.1
All three lake regions	82	17.2
TOTAL	**476**	**100**

Appendix 4. Profiles for the respondents' lake-use by region, including significant chi-squared results for region differences, PLUMS 2015-2016

	Lake region					
Purpose	**Diefenbaker–Qu'Appelle**	**South of Diefenbaker–Qu'Appelle**	**North of Diefenbaker–Qu'Appelle**	**Two lake regions**	**All three lake regions**	**TOTAL**
Fishing*	73.5% *n* = 72	60.9% *n* = 39	77.6% *n* = 52	81.4% *n* = 105	82.9% *n* = 68	76.4% *n* = 336
Swimming	72.4% *n* = 71	75.0% *n* = 48	65.7% *n* = 44	68.2% *n* = 88	70.7% *n* = 58	70.2% *n* = 309
Boating*	75.5% *n* = 74	85.9% *n* = 55	61.2% *n* = 41	76.0% *n* = 98	70.7% *n* = 58	74.1% *n* = 326
Recreation	72.4% *n* = 71	67.2% *n* = 43	59.7% *n* = 40	62.8% *n* = 81	63.4% n = 52	65.2% *n* = 287
Work*	7.1% *n* = 7	4.7% *n* = 3	7.5% *n* = 5	6.2% *n* = 8	18.3% *n* = 15	8.6% *n* = 38
Farm[+]	3.1% *n* = 3	1.6% *n* = 1	0.0% *n* = 0	1.6% *n* = 2	1.2% *n* = 1	1.6% *n* = 7
Cabin**	35.7% *n* = 35	59.4% *n* = 38	44.8% *n* = 30	30.2% *n* = 39	36.6% *n* = 30	39.1% *n* = 172

Note. Valid percent (%, first row) and frequency (*n*, second row). *p<0.05; **p<0.01; [+]few cases.

Appendix 5. Frequency and percent results for awareness of non-native mussels, PLUMS 2015-2016

	Yes		No	
Have you heard about?	**Frequency**	**Percentage (%)**	**Frequency**	**Percentage (%)**
Zebra mussels^{+}	378	86.7	58	13.3
Quagga mussels^{++}	141	32.6	291	67.4

Note. $^{+}$4 respondents did not answer; $^{++}$8 respondents did not answer.